COMPARING METHODOLOGIES TO ASSESS TRANSPORTATION AND AIR QUALITY IMPACTS OF BROWNFIELDS AND INFILL DEVELOPMENT

INTERIM DELIVERABLE OF IN-PROGRESS WORK

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EXECUTIVE SUMMARY

States and communities across the country are actively pursuing development strategies with environmental benefits. TEA-21 provides for over 100 new transit starts. Recently states and communities have passed hundreds of ballot initiative at the state and local level preserving open space, increasing development around transit, and providing for increased brownfields redevelopment. Each community has a different set of economic, environmental, and community reasons for pursuing their chosen development path. However, such decisions can help communities meet national environmental standards by reducing vehicular emissions, improving water quality, and remediating contaminated lands.

In many cases this represents a new approach to improving environmental quality. States and communities are anxious to "take credit" for their development-related environmental improvements. The Agency needs to develop new mechanisms to meet this need. This study is a step in recognizing the environmental benefits of community development decisions.

Many communities have made brownfields redevelopment and increased infill a priority of local economic development decisions. Successful brownfields and infill development can make auto trips shorter and other modes of transportation more convenient leading to reductions in tailpipe emissions. If EPA could recognize, in State Implementation Plans (SIPs), the emissions reductions produced by brownfields redevelopment and infill development, then cities, regions and states could get credit for development actions that are good for the environment.

Before EPA can evaluate SIP applications including such emissions reductions, the Agency must establish a methodology for quantifying the air emissions impacts of brownfields redevelopment. This report describes four possible methodologies. In order to help understand the advantages and disadvantages of each methodology, test applications of each were performed in four cities.

Many brownfield redevelopment and infill projects are expected to have air quality benefits relative to the status quo baseline, because in the baseline growth has been, and is expected to continue, locating in suburban and exurban areas. Such development produces substantially more vehicle travel and emissions than development on infill sites. The greater the difference between the travel produced locating at an infill site, and the travel that would have been produced by locating at a suburban or exurban site, the greater the emissions benefit of the infill location.

Each methodology examined here is a different answer to the question: if the infill development for which emissions credit is being claimed had not been built, where would the development ―the "growth increment"―have gone instead?

Methodology 1: Growth would have gone to a single "typical" greenfield site

Methodology 2: Growth would have gone to the fastest-growing parts of the region

Methodology 3: Growth would have been distributed through the region, in amounts determined by the local land use model

Methodology 4: Growth would have been distributed through the region, in amounts proportional to the distribution of all other growth.

Results so far suggest Methodologies 2 and 4 hold particular promise

The test results suggest that Methodologies 2 and 4 hold particular promise as EPA seeks a methodology that can be widely applied:

- **Methodology 2** Assumes that growth would have joined other growth in the fastest-growing urban and suburban areas of a region. This methodology picks the 16 fastest-growing suburban traffic analysis zones (TAZs), and 4 fastest-growing urban TAZs, and distributes the growth increment evenly among them.

- **Methodology 4** Assumes that the growth would have dispersed widely throughout the region. Specifically, that the growth increment would have been distributed through the region in precise proportion to all other growth. For example, if between the year the application for credit is submitted, and the year in which the emissions credit is claimed, 5% of all regional growth is projected to locate in a given suburban TAZ, then Methodology 4 assumes that 5% of the infill growth increment would have gone to that TAZ.

Methodologies 2 and 4 have two substantial advantages over 1 and 3:

- **Objectivity.** Both are objective and transferable from region to region in a way that Methodology 1, which picks a single greenfield site for comparison to the infill site, can be only very rarely.

- **Relatively low resource demands.** Methodology 3, which uses a regional land use model to forecast the market reaction to an infill development, is objective, but far more resource-intensive than Methodologies 2 and 4. Most regions do not have a land use model at all.

- **Conservative.** Unlike methodology 1 both methods 2 and 4 specifically allocate some of the growth to urban areas—creating a conservative estimate of emissions reductions.

Methodologies 2 and 4 have different advantages

In some cities, Methodologies 2 and 4 will not produce substantially different results. In some fast-growing cities, growth locates in a few fast-growing sections of the city. For regions like these, results for Methodologies 2 and 4 will be driven by many of the same TAZs. In regions where growth is more broadly distributed, Methodology 4 is likely to produce more accurate results because it captures growth in all TAZs.

All else being equal, Methodology 4 is likely to be more accurate across a broad range of regions, exhibiting a broad range of growth patterns. However, in requiring that the analysis look at every TAZ in the region, and in several other respects that are detailed in the body of the report, Methodology 4 is somewhat more difficult to perform. Methodology 2 is likely to produce results similar to Methodology 4 in certain cases, and so could conceivably be a low-resource substitute in cases where a region could demonstrate that most growth is occurring in the fastest-growing area. In the end, however, both 2 and 4 require the services of a good travel modeler, and any such person should be able to perform the additional work required in Methodology 4 in roughly a day's worth of labor.

Final evaluation awaits more results

We still await additional pilot project methodology test results from all pilot project cities, and these results will provide additional data on the performance of the methodologies under different conditions.

INTRODUCTION

States and communities across the country are actively pursuing development strategies with environmental benefits. TEA-21 provides for over 100 new transit starts, applications for which arrive with supporting land use policies. States and communities have passed hundreds of ballot initiative at the state and local level preserving open space, increasing development around transit, and providing for increased brownfields redevelopment.

Many communities have special concern about a dramatic increase in the amount of unused industrial land, called brownfields. As industry leaves central cities, new industrial sites proliferate in widely dispersed areas located in rural areas at the edge of metropolitan areas, raising a variety of environmental and economic concerns. This type of development increases energy use in transportation—and, as a result, greenhouse gas emissions—and discourages recycling of wastes by increasing transportation costs. At the same time agricultural land, wetlands and forested wildlife habitats are lost to new development. The U.S. Conference of Mayors has identified brownfields as one of the most important barriers to economic redevelopment in cities.

Each community has different economic, environmental and community reasons for pursuing their chosen development path. However, such decisions can help communities meet national environmental standards by reducing vehicular emissions, improving water quality, and remediating contaminated lands. Several EPA studies have shown that brownfield redevelopment, and other kinds of infill development, can reduce transportation emissions of all kinds, and preserve open space and habitat.[1] The Environmental Protection Agency has several reasons to develop new mechanisms to recognize these benefits. First, states and communities desire to have the environmental benefits of their development-related policies recognized, where appropriate, in regulatory frameworks. Second, if EPA could recognize, in State Implementation Plans (SIPs), the emissions reductions produced by brownfield redevelopment and infill development, then cities, regions and states would have an additional incentive to promote this type of development, supporting EPA in its mandate to help clean up brownfields. This report is part of EPA's effort to develop mechanisms to quantify and recognize where appropriate the air emissions reductions benefits of brownfield redevelopment and infill development.

Before EPA can evaluate SIP or other regulatory applications that include land-use-based emissions reductions, the Agency must establish a methodology for quantifying their air emissions impacts. This report describes four possible methodologies. In order to help

[1] William Schroeer and Eliot Allen, "The Impacts of Infill vs. Greenfield Development: A Comparative Case Study Analysis," U.S. Environmental Protection Agency, Office of Policy, EPA 231-R-99-005, September 2, 1999; and US EPA, Office of Policy, "Project XL and Atlantic Steel: Supporting Environmental Excellence and Smart Growth," EPA 231-R-99-004, September 1999.

understand the advantages and disadvantages of each methodology, test applications of each are being performed in four cities.

Several of the test applications are not yet complete. In order to perform the most accurate tests, EPA is working with the transportation modeling departments in Baltimore, Chicago, and Dallas. We appreciate their assistance with this study, and recognize that they have substantial other responsibilities. While Baltimore and Dallas have reported Methodology 1 results, Chicago is still producing Methodology 1 results, and Baltimore and Dallas Methodology 2 results are not yet complete (see Figure 1).

Figure 1: Methodology tests being performed in each city, and the current status.

Region	**Method 1**	**Method 2**	**Method 3**	**Method 4**
Atlanta	Complete	Complete	Preliminary result	Complete
Baltimore	Complete	In process		In process
Chicago	In process			
Dallas	Complete	In process		

This report describes results received thus far, and draws conclusions where possible given the results so far.

DESCRIBING THE FOUR METHODOLOGIES

Each methodology has the same goal: quantify the air emissions impacts of redeveloping brownfields or developing other infill properties. Each methodology differs in assumptions, complexity, and relative ease of application. This section describes each methodology.

Starting assumptions for all methodologies

The reasoning underlying all methodologies is the same: that *developing* an infill location will result in fewer auto emissions than *not developing* the location. Specifically:

1. The metropolitan region will continue to grow.

2. That growth is projected to locate mainly at the region's edge.

3. This growth pattern is largely responsible for producing the region's current transportation patterns.

4. The infill site is an opportunity to shift some of this growth inward, increasing regional convenience and accessibility, and reducing future driving.

Transportation literature suggests travel emissions resulting from infill would be lower than emissions resulting from the same project built on a region's fringe especially when:

1. the proposed development would include high densities, a mix of uses, and would be located near transit, and would therefore generate fewer total auto trips than comparable amounts of development placed in locations without these features; and

2. the proposed development would be regionally central to more activities, so auto trips to and from the site would on average be shorter.

Previous work by EPA has quantified the magnitude of potential improvement in the transportation and environmental performance of a development if located to produce regional and transit accessibility. The EPA Office of Policy study "Transportation and Environmental Impacts of Infill and Greenfield Development" found that locating development on regionally central infill sites can produce emissions benefits when compared to locating that same development on greenfield sites on the fringe of the currently developed area. In three case studies, per-capita VMT associated with a development site was reduced by as much as 61% at infill sites compared to the greenfield sites, and NO_x emissions were reduced by 46% to 51%.[2] This and related literature suggests that infill projects may reduce emissions relative to a regional baseline.

Because most region's SIPs expect continued suburban and exurban development, an increase in infill and a decrease in development at the fringe should be an emissions reduction not already anticipated in the SIP, and thus "surplus."

Naturally, in order for the emissions reduction to be "surplus," the development being analyzed must be an increase in infill development. If a newly proposed infill development simply absorbs growth already anticipated to go to another infill development, no new infill has occurred, and no surplus emissions reduction will be generated.

All methodologies assume a common starting point: that the growth whose emissions benefits will be analyzed will locate at a discrete infill site or set of infill sites. Once that site has been located, the next question is, "what would have happened had this brownfield not been redeveloped, or this infill project not been incentivized? Where would that increment of growth have gone instead?" The four following methodologies are four different ways to answer that question.

Methodology 1: Growth would have gone to a single greenfield site

Rationale

Methodology 1 is the simplest, and conceptually the most straightforward, methodology. Methodology 1 assumes that if growth were not to locate at the infill location, then it would locate at a discrete greenfield location.

One can think about Methodology 1 in two ways. First, it can represent the likelihood that, if an infill development is not competed, then a project similar to it in size and use mix will be developed on a discrete greenfield which can be identified. Perhaps not by the same developer or project consortium, but developed in response to market demand in any case. In many cases metropolitan planning organizations can either forecast with some accuracy where major projects will next locate, or explicitly guide that location process by identifying growth areas. For example, San Diego has a highly structured growth management system that designates the "next" development areas. San Diego was one of the cities that participated in the EPA study that led up to the pilot projects reported on in this study. San Diego chose as their greenfield site a site designated

[2] William Schroeer and Eliot Allen, "The Impacts of Infill vs. Greenfield Development: A Comparative Case Study Analysis," U.S. Environmental Protection Agency, Office of Policy, EPA 231-R-99-005, September 2, 1999.

Priority One for development. San Diego could say with some certainty that this site was "next in line" for development.

Second, Methodology 1 represents the possibility that, if an infill project is not completed, then a project similar to it in size and use mix will be developed on a greenfield *similar to* the site or sites analyzed. That is, the analyzed greenfield/s represent/s the location and design *characteristics* of greenfield projects likely to be built, even if the growth does not go to a single specific analyzed parcel.

The Baltimore, Chicago, and Dallas analyses reported in this study all used a single discrete greenfield location. However, they did not have a next-in-line to develop greenfield, and we used professional judgement to identify a greenfield site that could absorb the proposed amount of growth, and would be a plausible location for it.

The Atlanta analysis reported in this study selected three plausible greenfield locations, chosen both to represent both the general greenfield development options available in the Atlanta region, and to capture important variables that help determine travel behavior:

Location	**Development density**	**Regional location**	**MARTA rail served?**
Atlantic Steel	Urban	Central	Yes
Cobb/Fulton	Suburban	Suburban	No
South Henry County	Suburban	Exurban/Rural	No
Sandy Springs	Urban	Suburban Infill	Yes

The South Henry and Cobb/Fulton sites were judged consistent with the region’s projected suburban and exurban growth. In other words they are thought to be typical of where new growth is going. As a result they are believed to be the most reasonable comparison sites. The Perimeter Center/Sandy Springs site was judged a less likely destination for growth not absorbed at the Atlantic Steel site, and was chosen as a conservative point of comparison.

Possible adjustment: Adjust for growth that would have gone to infill anyway

Unlike the other three methodologies, this approach does not assume that the infill site takes growth from any other infill site. It assumes all growth is displaced from the greenfield site. The infill development for which credit is being claimed may absorb some of that already-planned development, reducing infill in adjacent areas. On the other hand, it is also possible that the new development will spur additional infill development in the vicinity. This may be especially likely where a proposed development is designed as a catalyst and/or an anchor around which development can begin re-entering a brownfield zone.

To make Methodology 1 as conservative as possible, one would ignore possible catalyst effects, and subtract from the project all development already proposed for the infill area. In the Atlanta pilot project, total infill development size would be 23,000 new jobs and residents. Projected growth for Midtown in the development period was 4,700 new jobs and residents. If all of those projected jobs and residents simply located in the Atlantic Steel development, then only 80% of the infill project growth would be "new" growth in Midtown. In that case, any credit should be scaled down by 20% to reflect only the new increment.

Methodology

Step 1: Select site pair

Select a site pair consisting of a greenfield site and a brownfield site, each of which could absorb a similar amount of growth when built out at locally prevailing densities.

Step 2: Model travel behavior

Run the regional travel model twice, once with development added at the infill site, and once with same amount of development added to the selected greenfield site/s.

Step 3: Model emissions

The travel model output will include VMT, which can be used as an input to MOBILE to produce emissions under the infill scenario and the greenfield scenario.

Step 4: Adjust for growth that would have gone to infill anyway

Total infill development size would be 23,000 new jobs and residents. Projected growth for Midtown was for 4,700 new jobs and residents. Thus, it could be argued that only 80% of the infill project growth is "new" growth in Midtown. Thus any credit should be scaled down by 20% to reflect only the new increment.

Advantages

Choosing one, or perhaps two or three, greenfield sites for comparison to the infill site has two substantial advantages:

1. It may represent the most likely development scenario, especially under a comprehensive planning program such as San Diego’s.

2. It is relatively straightforward. Picking and analyzing a single site (or small number of sites) is potentially less burdensome than several of the other methodologies studied.

Disadvantages

1. Growth may not locate at a single site or set of sites, resulting in overestimate of intrazonal trips in the case of mixed use developments.

2. The process of choosing a "most likely to develop" site cannot be made objective, unless a region has a very well structured planning process.

The remaining three methodologies attempt to overcome these two disadvantages.

Methodology 2: Growth would have gone to the fastest-growing parts of the region

Methodology 2 assumes that growth at an infill site would otherwise have located in the fastest-growing parts of the region. Further, the methodology assumes that the fastest-growing parts of the region are a) predominantly in the suburbs, but also b) partially in the central urban area.

Rationale

Methodology 2 assumes that *most* growth not located on an infill site would otherwise go to suburban areas, since that is where most growth locates now. Methodology 2 also assumes that *some* growth not located on an infill site would otherwise go to other infill sites, under an assumption that if a developer and its customers desire to locate on an infill site, they may also have been willing to look at other infill sites.

Methodology

Step 1: Divide the region into "urban" and "suburban" TAZs

Many TAZ-based modeling systems classify their TAZs according to the predominant development type and TAZ location (based on the TAZ’s population and/or employment density and a ‘distance to CBD’ measure). For example:

1. CBD
2. Urban High Density-Commercial
3. Urban Residential
4. Suburban Commercial
5. Suburban Residential
6. Exurban
7. Rural

In this system, types 1, 2, and 3 would be "urban," and types 4, 5, and 6 would be suburban. TAZs in type 7 would not be part of the pool of potential TAZs to receive growth.

Step 2: Find the fastest-growing urban and suburban TAZs

Those TAZs showing the fastest growth are those most attractive to the market, and thus the ones most likely to attract new growth. Select the following:

- 4 fastest-growing urban TAZs
- 16 fastest-growing suburban TAZs

This ratio reflects the fact that growth currently predominantly goes to the suburbs in most urban regions.

Step 3: Distribute infill growth to the selected urban and suburban TAZs

Distribute across the selected TAZs the same number of jobs and housing modeled as having gone to the infill site. For example, if the infill site was modeled as having added 1000 new jobs and 1000 new households, then add the following to the selected urban and suburban TAZs:

	Total	Per TAZ	# of TAZs
Urban jobs	200	50	4
Urban households	200	50	4
Suburban jobs	800	50	16
Suburban households	800	50	16

Step 4: Model travel behavior

Run the regional travel model twice, once with development added at the infill site, and once with same amount of development added to the selected urban and suburban high growth TAZs.

Step 5: Model emissions

The travel model output will include VMT, which can be used as an input to MOBILE to produce emissions under the infill scenario and the greenfield scenario.

Step 6: *Adjust for growth that would have gone to infill anyway*

Total infill development size would be 23,000 new jobs and residents. Projected growth for Midtown was for 4,700 new jobs and residents. Thus, it could be argued that only 80% of the infill project growth is "new" growth in Midtown. However, since we already put 20% of the "baseline" growth in urban TAZs, it would almost certainly overly conservative to again scale down credit by 20% as we did in Methodology 1.

Advantages

1. Objective/transferable
2. Relatively straightforward
3. More conservative than Method 1, because it allocates 20% of the growth to infill.

Disadvantages

1. No good basis for choosing fastest-growing 16 and 4 TAZs, as opposed to some other number. Number will represent different proportion of TAZs in different regions.

   As an alternative approach to Methodology 2, we considered the following approach:

   a) Rank TAZs by total growth in employment + population.

   b) Find mean growth and standard deviation. Find TAZs at or more than three standard deviations greater than the mean growth.

   c) Distribute the growth across those TAZs in proportion to the growth predicted to go to those TAZs in the baseline.

   Defining "fastest growing" in statistical terms not only solved the problem of varying numbers of TAZs from region to region, but also allowed the definition of "fastest" to respond to different regional growth patterns. We could also have done this by defining "fastest" as being a certain percentage of TAZs. However, the added complexity did not solve the fundamental weakness of this methodology, which is that there was no solid reason for choosing a cut-off above which TAZs were deemed "fast-growing."

Methodology 3: Growth would have been distributed through the region, in amounts determined by the local land use model

Rationale

Methodology 3 uses the assumptions about how regional growth will respond to a increase in infill that are built into a regional land use model.

The model DRAM/EMPAL (Disaggregate Residential Allocation Model (DRAM) and the Employment Allocation Model (EMPAL) was used to test Methodology 3 in Atlanta. DRAM/EMPAL does not make explicit assumptions about how a market responds to infill. Rather, the model attempts to model future land use patterns as a function of transportation accessibility, land availability (both physical, and as constrained by zoning) and past growth patterns. DRAM/EMPAL does not model decision-making by individual residents or employers, nor does land economics enter the model except indirectly through historical consumption trends. Rather, the model extrapolates past trends subject to a set of land use and transportation constraints.

Several other land use models attempt to represent urban land use economic decision making more explicitly. The pros and cons of the various approaches to regional land use (or transportation and land use) modeling are beyond the scope of this study. However, DRAM/EMPAL is the most commonly used such model in the United States, and was thus the obvious candidate for use in testing Methodology 3.

Methodology

Step 1: Select infill site

As in the other methodologies.

Step 2: Obtain DRAM/EMPAL forecast

Allow DRAM/EMPAL to reallocate housing and employment from a baseline forecast, while forcing growth to the infill site. One can use DRAM/EMPAL to perform this analysis in two ways.

The most conceptually "pure" approach is to perform two DRAM/EMPAL runs; one baseline, and one with the proposed development, each with the same number of jobs and housing (the "control total"). In the baseline run, DRAM/EMPAL distributes the control total across the region with no assumption about how much development occurs at the infill site. For the "infill run," the population and housing in the analysis zone where the infill is proposed is set manually to total existing + proposed development. With the infill development set manually, that many fewer jobs and housing will be available to the model to be allocated to the rest of the region, and totals in those zones will be slightly lower than in the baseline. The difference between the two is where growth would have gone in the absence of the infill project.

Step 3: Model travel behavior

Run the regional travel model twice, once with development fixed at the infill site, and once population and employment allocation by DRAM/EMPAL unconstrained.

Step 4: Model emissions

The travel model output will include VMT, which can be used as an input to MOBILE to produce emissions under the infill scenario and the unconstrained scenario.

Step 5: Adjust for growth that would have gone to infill anyway

Because in this methodology one is working directly with land use forecasts, one could manually fix in DRAM/EMPAL the amount of infill growth expected in zones beyond that where the infill is being proposed. This manual adjustment would depend on how much already-expected infill one expected to be absorbed by the new infill. For the Atlantic Steel analysis, we wanted to keep the methodologies comparable, and so applied the same 20% reduction in infill benefits as in the other methodologies, reflecting the fact that 20% of the Atlantic Steel infill amount was already project to locate in Midtown.

Advantages

1. These four methodologies seek an answer to the question "How will regional land use change in response to increased infill?" Regional land use models were developed to answer precisely this type of question, *if the proposed infill development is large enough*.

2. Objective/transferable.

Disadvantages

1. Regional land use models were not developed to react to small changes in regional zoning, so not appropriate for analyzing small developments.

2. Requires region to run a regional land use model. Even with such a model already installed and running, individual runs are quite resource intensive. This is the most resource intensive methodology. Many regions do not have a land use model.

Methodology 4: Growth would have been distributed through the region, in amounts proportional to the distribution of all other growth

Methodology 4 assumes that the infill site's growth increment would otherwise have "followed" all other new growth in the region. If 5% of regional employment growth went to a given TAZ, then 5% of the infill's employment would have gone to that TAZ, etc., for all TAZs regionwide.

Although Methodology 4 assumes that the growth increment would have "followed" other growth, the methodology takes a shortcut past actual allocation. Since the goal of each analysis is to determine the travel associated with the growth increment, this methodology goes straight to quantifying that travel.

Rationale

Methodologies 1 through 3 rest on assumptions that the growth increment is unique to a greater or lesser extent. In Methodology 1, either the growth increment is so unique that it would locate in a single site, or in a set of sites whose characteristics are essentially the same as a single site. In Methodology 2, the increment is special in that it would locate only in the fastest-growing TAZs. In Methodology 3, the increment is special in that it would cause a unique ripple in the chain of land consumption. All of these assumptions about the uniqueness of the growth increment have merit, and may be empirically supportable in cases. Methodology 4, however, assumes that there is nothing special about the growth increment, or at the least, assumes that the analyst cannot reliably know whether the increment is special. If the brownfield is not redeveloped, then the safest assumption is that the increment will behave like all other growth. Therefore, Methodology 4 estimates the travel impacts of a scenario in which growth not absorbed at the infill site instead follows average new development patterns.

Another way to think about this is that Methodology 1 assumes that the increased infill displaces growth from a *single* typical suburban site, Method 2 assumes that growth is pulled from *20* different locations, Method 3 tries to analyze growth in the context of all other growth and determine specifically which TAZs the growth comes from. Methodology 4 says an infill site draws a little from every place that is expected to get growth, and the amount it pulls is proportional to the amount that was going there initially.

If the growth increment is distributed in the same pattern as all other regional growth, then it will have the same travel characteristics as all other regional growth. Thus, calculating the travel characteristics of "all new regional growth" in the absence of the infill development will also give one the travel characteristics of the growth increment. The task of Methodology 4, then, is to calculate the *average travel behavior and average emissions of all new growth.* This is distinct from the average travel behavior and average emissions of the region.

Methodology

Step 1: Select infill site

As in the other methodologies.

Step 2: Calculate travel behavior of all new growth predicted for the region, without proposed infill

Calculate the difference in total travel between two years; say, 2000 and 2010:

	Out year (2010) regional VMT from regional travel model without infill project
—	Base year (2000) regional VMT from regional travel model
	VMT associated with all new jobs and housing (between 2000 and 2010)

If regional mileage is predicted to be 1,000,000 miles in 2000, and 1,200,000 miles in 2010, then:

	2010 regional VMT from regional travel model without infill project:	1,200,000
—	2000 regional VMT from regional travel model:	1,000,000
	VMT associated with all new jobs and housing between 2000 and 2010:	200,000

This calculation produces a difficult-to-interpret denominator: VMT/jobs+housing. This figure must be further broken down into travel behavior associated with each new job and each new housing unit.

The detailed discussion of how "per household VMT" and "per employee VMT" estimates can be decomposed from total regional VMT change is given in the Appendix.

Step 3: Calculate travel VMT associated with proposed infill development

Once one knows the travel associated with each *new* job and each *new* employee, one can calculate:

	Miles driven associated with 1 new job × new jobs proposed for the infill site
+	Miles driven associated with 1 new person × new population proposed for the infill site
=	New miles driven if infill-project-sized growth follows average dispersal pattern

Step 4: Model emissions

Apply mobile-source emissions factors to the VMT from Step 3. Note that the previous methodologies all produce VMT statistics for a road network, which include statistics on VMT by speed range that are used by MOBILE. This methodology estimates only the change in average VMT. In order to calculate the emissions associated with the change in these VMT, one must apply regional average emissions factors.

Step 5: Adjust for growth that would have gone to infill anyway

As in the preceding three methodologies, it could be argued that only 80% of the infill project growth is "new" growth in Midtown. Thus any credit should be scaled down by 20% to reflect only the new increment.

Advantages

- Assumes that growth is drawn proportionately from all over the region—like a housing filtering prediction.
- Objective/transferable
- Provides a facsimile of a scenario in which growth that would otherwise have gone to the infill site is "widely dispersed", without having either to run a land use model like DRAM/EMPAL, or adjust the housing and employment characteristics of every TAZ.

Disadvantages

- Does not separate out the effect of changing trip-making behavior for the base population, including changes produced by new roads and transit.
- Does not analyze a specific land use. That is, as described, does not change a land use allocation which is then used as a travel model input. Thus, Methodology 4 cannot produce system performance measures (average trip times, etc.). At first this may appear more a concern for regional policymakers, who find these measures useful, than for EPA, for whom these measures are not an input to a SIP-credit granting decision. However, not running a travel model may mean that the policymakers and EPA evaluators miss any non-linear effects of the growth increment on the transportation system. For example, if a region's highways are congested, the additional growth increment may have different effects than the base growth. It is likely that this disadvantage would not manifest itself for any but the largest growth increments.
- In order to limit the effect of new transportation infrastructure on the results, one should compare the base and out year runs for the with the most comparable transportation networks for each year. The assumption of little change in transportation networks may be unrealistic.

RESULTS OF TEST APPLICATIONS OF THE FOUR METHODOLOGIES

Baltimore

Methodology 1

The Baltimore pilot project, in consultation with project consultants and the Baltimore Metropolitan Council, selected a greenfield in Carroll County and an infill site on the harbor. The infill development would place 400 households on the site of former U.S. Steel Shipyard facilities, and 800 jobs on 80 acres at an old Exxon site nearby.

The greenfield development would place the same amount of housing and jobs on 270 acres in Carroll County, a fast-growing area near Baltimore.

Results

VMT

The Baltimore Metropolitan Council (BMC) modeled travel behavior both by using a regional travel model full network run, and by using incremental growth in vehicle trips to and from each site to estimate change in VMT and mobile source emissions from the growth increment.

The full network model runs reported lower regional VMT with infill than with no growth. BMC modelers spent a great deal of time ensuring that each run was done consistently and cannot explain these counter-intuitive results. The regional emissions analysis also reports lower emissions in the infill scenario than in either the no build or the greenfield scenario. While these results certainly support a program of infill, we believe that they are not satisfactorily explainable, and thus are a poor basis for policy making. Therefore we do not report the overall network results.

Instead, we recommend using in this case the analysis of incremental growth in vehicle trips to and from each site to estimate growth in VMT and mobile source emissions. That analysis produces the following results:

	Average veh. Trip distance		New veh. Trips		New VMT	
Infill site	7.68		3,895		29,914	
Greenfield site	9.86		4,688		46,224	
Delta	2.18	28% higher	793	20% higher	16,310	55% higher

EMISSIONS

Because the network run was not deemed reliable, emissions were also estimated at the project level. Rather than performing a standard MOBILE analysis, trip emissions were built up from emissions component factors (cold starts, running, idling, hot start, and hot soak), using the average regional travel speed (23.9 mph) for all trips.[3]

Total project-level emissions:

Total Emissions, in Tons

	NO_x		VOC	
Infill	0.05		0.11	
Greenfield	0.07		0.15	
Difference	0.02	Greenfield 40% higher than infill	0.04	Greenfield 36% higher than infill

Methodology 2

Methodology 4

Results discussion

VMT

These results suggest:

1. That network modeling may be unreliable below a certain level of development, in certain situations and using certain models. (Dallas network modeling provided reasonable results with a small development.) We are working with BMC to understand this phenomenon, and if possible to establish a minimum size of development necessary for robust network –wide analysis.

2. That the Baltimore infill project, when analyzed using a site-based approach, produces roughly the same VMT and emissions advantage as infill elsewhere analyzed using a network-wide approach.

[3] Additional detail given in "Baltimore Infill Emissions", November 15, 1999, memo from Pihl and Schroeer to Geoff Anderson.

The results suggests that developments of small size should still be able to participate in infill credit programs. Further pilot project work will focus on establishing a minimum development size for robust modeling. An alternative approach might simply be to require that counter-intuitive results using a network method be checked using a site-level method. All else equal, EPA would prefer full network modeling over snapshots of single TAZs. Single TAZ comparisons misses network effects, do not capture trip diversions, and generally must provide a less full picture of the impacts of infill versus other development.

EMISSIONS

Because emissions were not calculated from a network run, but are simply functions of trips and VMT generated, they are of the same magnitude as the VMT change.

Dallas

Methodology 1

The study consultants, in consultation with North Central Texas Council of Governments (NCTCOG), the City of Dallas Brownfields staff, and other pilot project staff, selected South Side on Lamar as the infill site, and the Highway 121 corridor/McKinney area for the greenfield development. The sites epitomize their respective types of redevelopment and development. Participation by NCTCOG and the City of Dallas Brownfields staff helped assure that the two locations were fair examples of each site type.

Infill site

South Side on Lamar, spanning several addresses on South Lamar Street, is a 17.5-acre site that formerly housed the first Sears Catalog Store. The site includes five buildings that total 1.4 million square feet and approximately 1,500 parking spaces, and is already under redevelopment.[4]

Planned site use is residential, retail, suites, hotel, restaurant, catering business, food mart and offices. Phase I development includes construction of 175 lofts which were leased beginning in January 1998; an additional 225 will be constructed during Phase II. 1,500 retail jobs are planned.

Thus, modeled development on the site included:

- 400 units of housing, and 1,500 jobs

[4] Site description from EPA Region VI.

The site is located with 1/10 mile of Cedars Dallas Area Rapid Transit (DART) light rail station, and is representative of transit-accessible infill development in the region.

Greenfield site

The Highway 121 corridor is the fastest-growing area of the region. It includes the city of McKinney, with 13% growth in 1997, when it was the fourth-fastest growing city in the region. A 225-acre greenfield site was selected in McKinney. The same mix of development was placed on the McKinney greenfield as on the South Side at Lamar infill site, for a total of:

- 400 units of housing, and 1,500 jobs.

NCTCOG believes that given the high growth rate in the McKinney area, this type of development could be seen in the area.

Results

	Greenfield site	Infill site	Infill as a % of greenfield
Emissions			
Total Weekday Vehicle Emissions (Tons/Day)			
Hydrocarbons (VOC)	0.088	0.064	73%
Nitrogen Oxides	0.118	0.103	87%
Carbon Monoxide	0.818	0.603	74%
Vehicle Miles Traveled			
Weekday VMT	43,598	31,523	73%

Results discussion

Although the modeled development was fairly small, the NCTCOG network model showed a substantial performance difference between the brownfield site and the greenfield site.

Methodology 2

Chicago

Methodology 1

Atlanta

Methodology 1

The Atlanta pilot project selected one infill site, the Atlantic Steel site in Midtown, and worked with regional stakeholders to select the three greenfield sites as listed below.[5] The pilot project then modeled the impacts of locating on each site a mixed-used development of 17,483 jobs and 6,000 residents.

Results

The substantial congestion in the Atlanta region, together with the large size of the growth increment, means that emissions changes are substantially larger than the VMT changes that drive them. The extremely large percentage changes in VOC emissions are a function of small decrease in VOCs produced by the addition of some transportation infrastructure at the infill site and the resulting decrease in congestion at a severe bottleneck. This result should not generally be expected, nor does EPA expect it to

[5] For a detailed discussion of the site selection process, see Hagler Bailly, "Transportation and Environmental Analysis of the Atlantic Steel Development Proposal," November 1, 1999.

persist. The results are reported for completeness, but the absolute emissions changes should be emphasized in this case.

Method 2

Distributing the Atlantic Steel jobs and housing to the region's 20 fastest-growing TAZs Method 2 produced an increase of 409,282 VMT over the baseline, compared to 340,300 VMT at the Atlantic Steel site.

Method 3

Initial results from the DRAM/EMPAL run with growth manually adjusted and fixed at the Atlantic Steel site suggest that growth not locating at Atlantic Steel would produce 597,629 additional VMT. This estimate is preliminary pending clarification of several technical points with the Atlanta Regional Commission (ARC), and may be revised. For the purposes of this discussion, the preliminary analysis confirms that the Atlantic Steel development would draw growth from the suburbs, rather than from the city center. In his letter transmitting the results of the DRAM/EMPAL run, Bart B. Lewis, Chief of the ARC Research Division, noted:

> I have given the results of this run a very quick review against the original 2010 E+C output. They appear reasonable and consistent with the assumed shift in population and jobs. The employment redirected to the Atlantic Steel site is drawn from many tracts, but most of the jobs come from areas north of the CBD. This shifts the employment center of the region slightly southward, which, in turn, moves some households from the north side of the region to the south side. The net affect of the project on central Atlanta is to increase employment while having only a small impact on population.

Method 4

Between 2000 and 2010, newly-added employee and household in the Atlanta region are predicted to produce the following travel behavior:

Daily VMT	Interzonal trips	Intrazonal trips	Total
per employee	14.98	5.32	20.3
per household	50.90	7.8	58.7

Thus, if the growth proposed for Atlantic Steel infill followed average new growth, it would produce:

	Miles driven associated with 1 new job:	20.3	× new jobs proposed for the infill site	17,483	=	354,904
+	Miles driven associated with 1 new household	58.7	× new households proposed for the infill site	2,409	=	141,408
=	New miles driven if infill-project-sized growth follows average dispersal pattern				=	496,312

Results discussion

VMT

The four methodologies, including each of the three alternative sites from Methodology 1, generated the following estimates of VMT generated by the same, Atlantic-Steel-sized amount of growth:

Methodology	Modeled VMT	Benefit of infill, VMT	x 0.8 for 20% adjustment
Infill: Atlantic Steel	340,300		
M1: Sandy Springs	389,672	49,372	39,498
M2: Dispersed to 20 fastest-growing TAZs	409,282	68,982	NA: 68,982
M4: Dispersed in proportion to all new growth	496,312	156,012	124,810
M1: Cobb/Fulton	507,498	167,198	133,758
M1: Henry County	518,197	177,897	142,318
M3: Dispersed by DRAM/EMPAL	597,629 (preliminary)	257,329	205,863

Direct comparison between the network assignment methodology used for the three M1 individual sites, and the methods used for the dispersed scenarios, should be made with some caution. For example, the travel behavior of new growth in Methodology 4 is modeled using the 2010 Expected + Committed (E+C) network. That modeling produces slightly *less* VMT per household for new development than for existing development. Given that most data show trends toward more dispersed development and more VMT as a result, this counter-intuitive result deserves discussion. It also usefully illustrates important differences between the two methodologies.

That new development is projected to show lower VMT/household than existing development is likely due in part to a lack of transportation (particularly highway) enhancements over the modeled ten-year period. The 2010 E+C network finds the majority of regional roadway networks operating at or near capacity. In response, DRAM/EMPAL forecasts for 2010 more development in existing urban areas than many people expect absent some policy intervention. (The group of people who doubt the DRAM/EMPAL forecast includes the stakeholders in the Atlantic Steel process, who chose the largely outlying sites in methodology 1 as being the most likely destination for a growth increment of this magnitude.) This concentration tends to slow growth in VMT up to a point.

Methodology 4 had to use the 2010 E+C transportation network and land forecast because Atlanta does not yet have agreement on a transportation investment scenario for 2010. The 2010 E+C scenario is conservative because additional transportation capacity is likely to be added above the E+C scenario. Methodology 1 allows policymakers to respond to that likelihood by choosing sites that they believe will be growth locations after expected but not-yet-modeled transportation investments. Methodologies 2, 3, and 4 do not because in an effort to be objective, they operate off of a fixed forecast, and are limited by its limits, whatever they are.

All methods show VMT/day increasing as homes and businesses locate further from the Atlanta core. Of the methodologies, Methodology 4 appears to fit most intuitively with the Methodology 1 site estimates. Most development in Atlanta is occurring "farther" from the core than Perimeter Center, and closer than South Henry County; that is, in a band roughly as far out as the Cobb/Fulton site, if not farther. Stakeholders in the Atlantic Steel process thus judged Cobb/Fulton to be the site that best represented the characteristics of the site or sites where the growth increment would otherwise locate. VMT associated with development at the Cobb/Fulton site using Methodology 1 was only 2.2% different than the VMT estimated using Methodology 4.

THE STRENGTHS AND WEAKNESSES OF THE FOUR METHODOLOGIES

The section "Describing the Four Methodologies" discussed the conceptual advantages and disadvantages of each methodology. This section discusses the strengths and weaknesses of each methodology, taking into account both the conceptual advantages and disadvantages, and also how the methodologies actually performed in the pilots.

Each of the four methodologies has different strengths and weaknesses as tools with which to quantify the air emissions impacts of brownfields redevelopment. This section compares the methods on the basis of their:

- ease of their implementation;
- relative accuracy; and
- tendency to over- or under-estimate emissions savings.

This section also compares the 4 methodologies against other quantification methodologies currently in use in determining SIP credits (for instance methods used to quantify credits given under the voluntary measures program or credits assigned to TCMs).

The final report will also address issues of model sophistication, necessary size of development and scaling up, and potential for CO hot spots.

Highlights of evaluation so far

Method and base assumption	**Objective/ Transferable**	**Appears consistent with other methodologies?**	**Possible operational or other challenges?**
Methodology 1: Growth would have gone to a single greenfield site	No	With Method 4	Requires expert judgment about site/s for future growth
Methodology 2: Growth would have gone to the fastest-growing parts of the region	Transferable, but no good reason for using top 20 TAZs	Appears conservative so far	None
Methodology 3: Growth would have been distributed through the region, in amounts	Yes, to regions using a land use model	Appears high so far	Requires land use model

determined by the local land use model			
Methodology 4: Growth would have been distributed through the region, in amounts proportional to the distribution of all other growth.	Yes	With Method 1	None

In this initial evaluation, Methodology 4 appears to suffer from the least number of weaknesses.

[This section to be completed once all methodology tests are completed.]

APPENDIX: DETAILED METHODOLOGY FOUR DESCRIPTION

The following procedure was used to implement Methodology Four in Atlanta, using the TRANPLAN model. Some steps may be different when implemented elsewhere.

This analytical procedure uses two data sources:

(i) Auto-driver trip tables for two points in time, and

(ii) Socio-economic data for the same two points in time.

The individual steps employed are:

A. Two discrete land-use datapoints (years 2000 and 2010) are established, to include total population, households and population by zone (2000 and 2010). The net difference between each year is calculated, resulting in total 'new' employees, jobs, and households

B. Model procedures are employed to calculate the following measures (for both 2000 and 2010 model years):

- Total vehicle trips (SOV and group), by purpose (HBW, HBO, NHB)

  Since the model doesn't assign trips by these trip purposes, run vehicle 'auto-driver' matrices through a trip-length frequency reporting module.

- Calculate average vehicle trip lengths calculated for HBW, HBO, and NHB restricted matrices.

A. Derive an estimate of VMT (by purpose and year) by multiplying average vehicle trip lengths by total vehicle trips. Summarize average vehicle trips as follows:

- Average number of vehicle trips per employee = Total employees/Total HBW vehicle trips

- Average number of vehicle trips per household = (Total households/Total HBW vehicle trips) + (Total households/Total HBO vehicle trips) + (Total households/NHB trips)

  Reflects the basic premise that all trips are a household level decision, even if they don't begin from at the household level (e.g. NHB trips).

- VMT per employee = (Total employees/Total HBW vehicle trips)* Average trip length

- VMT per household = (Total households/Total HBO vehicle trips) * Average HBO vehicle trip length + (Total Households/Total HBW vehicle trips) * Average HBW vehicle trip length + (Total Households/Total NHB vehicle trips) * Average NHB vehicle trip length

A. The net change in (i) vehicle trips and (ii) VMT between 2000 and 2010 is determined by subtracting each year's subtotals (2000, 2010) established in step B. Revised trip lengths are calculated for all 'new trips' by dividing 'new VMT' by 'new trips'. Once new trip lengths are calculated, the average number of vehicle trips per 'new' employee and 'new' household is again estimated (part C). Total 'new' trips are multiplied by revised trip lengths to produced an average VMT estimates for each new employee' and household attracted to the region between 2000 and 2010.

B. The original estimates of 'VMT per household' and 'VMT per employee' are compared against the regionally dispersed estimates.